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AT? Why? WHEN? HOW? WHERE? WHO?

THE NIAGARA ESCARPMENT

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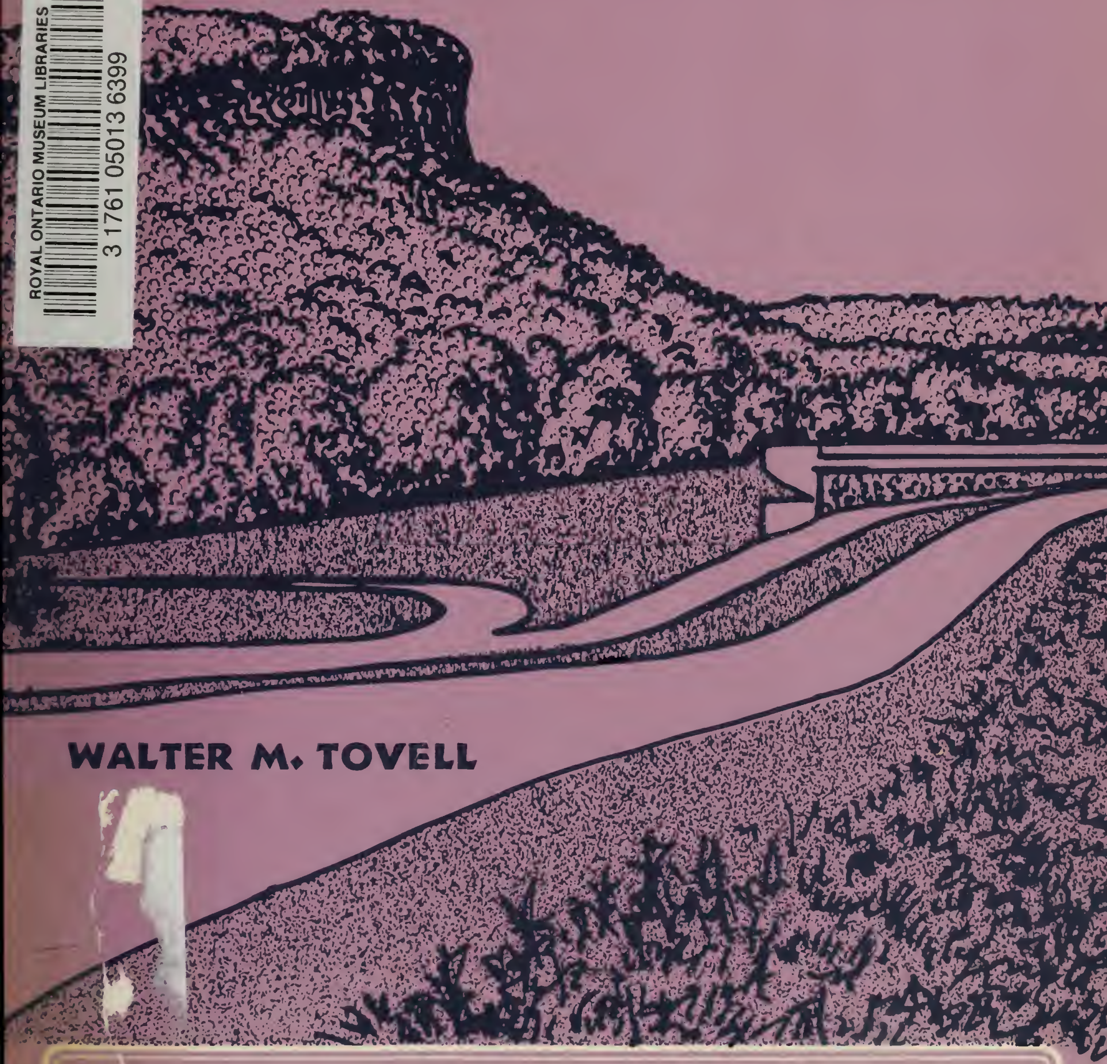

WALTER M. TOVELL

Royal Ontario Museum / University of Toronto

I keep six honest serving-men
(They taught me all I knew);
Their names are WHAT *and* WHY *and* WHEN
And HOW *and* WHERE *and* WHO.

RUDYARD KIPLING

ROYAL ONTARIO MUSEUM SERIES

WHAT ? WHY ? WHEN ? HOW ? WHERE ? WHO ?

1 *K. B. Brett:* WOMEN'S COSTUME IN EARLY ONTARIO
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WHAT? HOW?
Why? WHERE?
WHEN? WHO?

The Niagara Escarpment

by WALTER M. TOVELL

It is suggested that the reader follow this text with a road map of Ontario.

WHERE is the Niagara escarpment located?

The Niagara escarpment is shaped like a gigantic horseshoe. The eastern end begins in New York State, just south of Rochester, and runs eastward through Lockport parallel to the shore of Lake Ontario. The escarpment crosses the Niagara River into Canada from Lewiston, N.Y. to Queenston, Ontario. From there it continues eastward to Hamilton, northwestward across Ontario to Osler's Bluff and Blue Mountain near Collingwood, westward to Owen Sound, and northward to Tobermory at the tip of the Bruce Peninsula. Along this peninsula it forms the west shore of Georgian Bay. At Tobermory it disappears beneath the waters of Lake Huron, to reappear on Manitoulin, Cockburn, Drummond and St. Joseph's Islands. From there it extends to the western side of Lake Michigan, forming part of the shoreline in the Green Bay area. The western end of the horseshoe lies in Wisconsin.

This account deals with the part in southern Ontario which forms the boundary between Peninsular Ontario and the Lake Simcoe-Lake Ontario Lowlands, that is, the part between the Niagara River and the Bruce Peninsula.

WHAT is the Niagara escarpment?

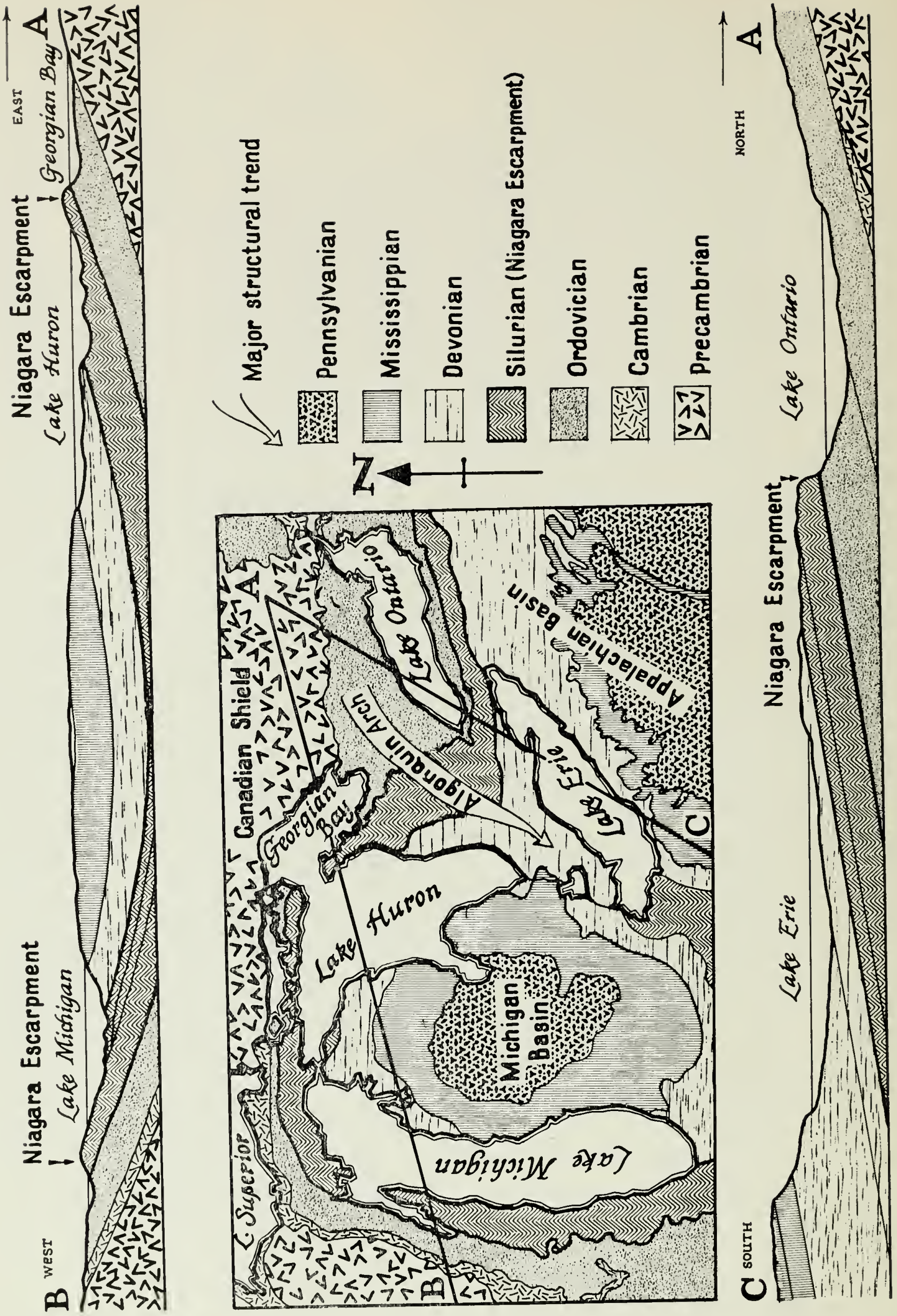
The Niagara escarpment is a topographic feature of variety and beauty. Essentially it is a product of erosion, the work of water over hundreds of millions of years. Its rocks are of sedimentary origin, being formed from muds, sands, and calcareous oozes laid down on the floors of prehistoric seas which covered this part of North America some 400 million years ago. In many places they have been mantled by clays and sands left by the Great Ice Age; these deposits have greatly transformed the escarpment profile. In other places the rocks are drowned beneath the central Great Lakes.

Its segments of rugged beauty make the escarpment a favourite spot for tourists and outdoor recreation. The Bruce Trail, a hiking route from the Niagara River to Tobermory, has done much to focus attention on its continuity. Several provincial parks and conservation areas as well are to be found along the escarpment, among them Inglis Falls at Owen Sound, the Devil's Glen at Singhampton, the conservation area at Terra Cotta, Glen Haffy Conservation Area near Mono Mills, and Ball's Falls near Jordan; to the south lies the extensive system of the Niagara Parks Commission. But many more such areas are needed to meet the ever-increasing demand for recreational space and to ensure the preservation of our natural assets.

The sedimentary rocks of the escarpment occur in nearly horizontal layers. Two of their units can be recognized readily by the amateur. The first is the red Queenston shale, which is evident in the northern part of the Niagara gorge and along the banks of the Niagara River below the escarpment. It can also be seen at the base of the escarpment near Owen Sound, and at many other places.

The second easily recognizable unit is the Lockport dolomite, a layer of hard rock which caps the escarpment throughout its course. Dolomite is similar to limestone (calcium carbonate), except that it also contains some magnesium. Geologists have described many subdivisions of this dolomite caprock. In recent government reports, for example, you will find that in the northern portion of the escarpment the name Lockport has been replaced by Amabel. Why more than one name? It is in part because the formation contains the remains of reefs, built in prehistoric seas by extinct animals and similar to those built by corals in tropical marine waters today. No two reefs are ever exactly the same, and neither are the deposits between

The face of the Niagara escarpment at Webster's Falls, above Dundas, Ontario. This photograph shows the sedimentary rocks formed from the beds of prehistoric seas, the sapping process which has worn away the face, a talus of angular material in the foreground, and at the top a layer of soil left by the glaciers.



The Niagara escarpment is the edge of a gigantic geological saucer which dips to a centre in the Michigan basin. This map shows the ages and distribution of the rocks associated with the area in plan and in two cross-sections.

them; as a result the rocks formed in association with reefs are also variable.

Between the Lockport-Amabel dolomites and the Queenston shale lie layers of other sedimentary rocks—sandstones, limestones, and more shales and dolomites. Their distribution follows a regional pattern. In outcrops between the Niagara River and Hamilton we find numerous beds of sandstones and shales, while further north, in the Owen Sound-Bruce Peninsula segment, there are few such units even though the strata are of the same age. You can readily see such variations in the field. At Queenston, and Lewiston, for example, outcrops along the banks of the Niagara River reveal buff-weathering sandstone layers, about 20 feet thick, overlying the red Queenston shale. The same succession can be seen in some road cuts around Hamilton; but at Owen Sound the Queenston shale is topped by a formation known as the Manitoulin dolomite. Such variations, or facies changes, represent different types of deposits formed at the same time but under different conditions and in different parts of the seas in which the deposits originated.

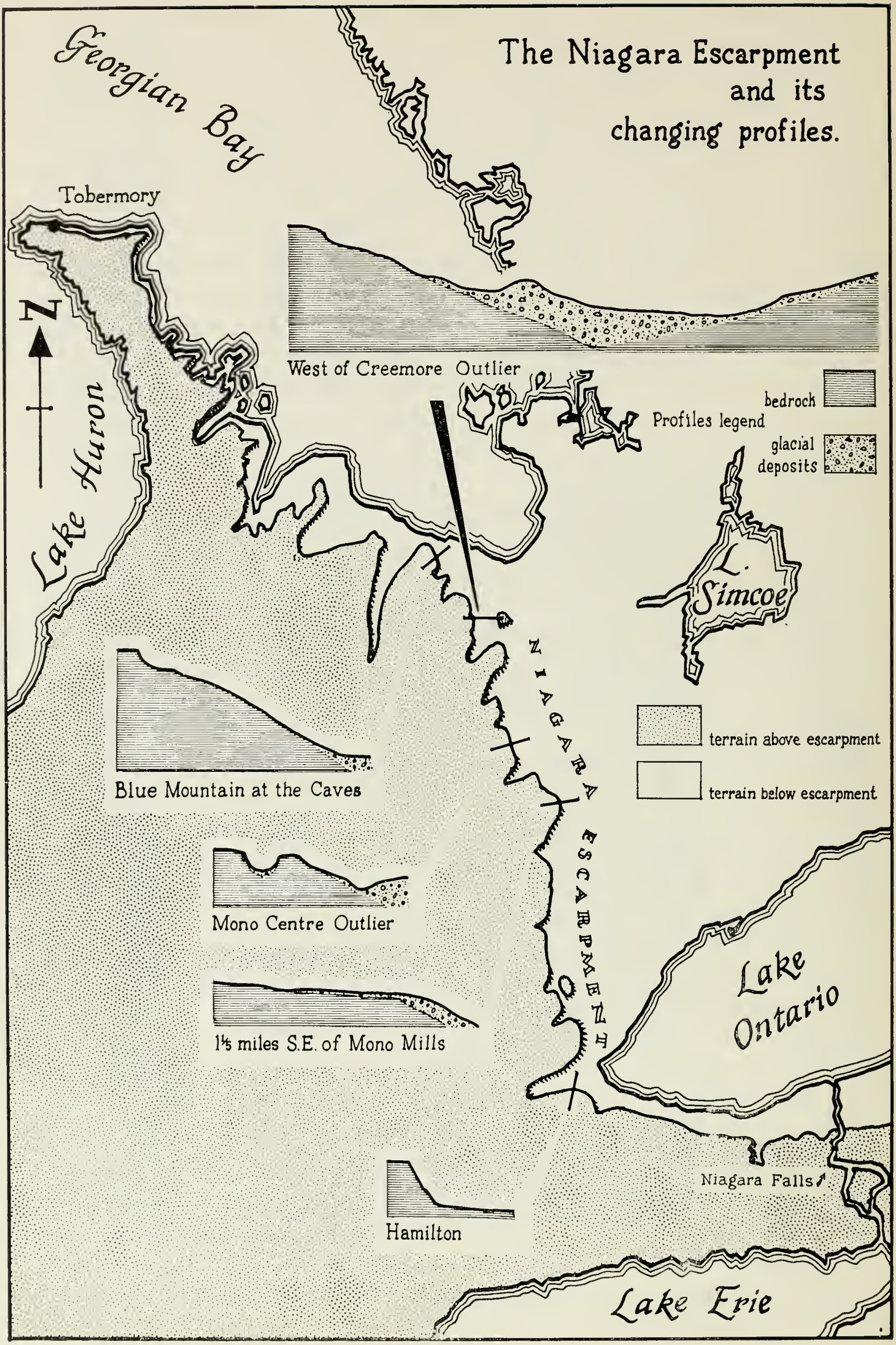
Queenston shale belongs to the Ordovician Period in the standard geological time scale. The strata lying above it belong to the lower and middle parts of the Silurian Period. Thus, along the base of the Niagara escarpment you can see directly what geologists call the Silurian-Ordovician contact, and a facies change associated with it. Facies changes also affect the shape and profile of the escarpment along its length. The Manitoulin dolomite, for example, forms a prominent step, or secondary escarpment, in the Collingwood-Owen Sound area.

Along the escarpment face we can determine the relative thickness of the different layers, their horizontal extent, and their relationship in time. But that is only part of the story. We get more information by drilling in southwestern Ontario, where the same layers are buried in the sub-surface. By examining cores and cuttings, the geologist can map in three dimensions the total distribution of rocks exposed along the wall.

We have already seen that from above, as on a map, the escarpment is shaped like a horseshoe. In cross-section, it is much more like the rim of an enormous saucer, which has its centre (the Michigan basin) in the state of Michigan.

In southern Ontario, the edge of the saucer is far from uniform. In the first place, parts of it are much higher than others. Near Queenston, the escarpment is about 500 feet above sea level. In the Bruce Peninsula, it varies between 600 and 900 feet. Yet, in between, around Collingwood, the elevation is more than 1700 feet. The rise is caused by a broad upfold in the rock formations, known as the Algonquin Arch. In effect it is a large crimp in one edge of the saucer.

Furthermore, the saucer edge in many places has been nicked or chipped. Valleys have been eroded into the escarpment wall at such places as the


The Niagara Escarpment
and its
changing profiles.
Georgian Bay
Tobermory
N
Lake Huron
West of Creemore Outlier
bedrock
Profiles legend
glacial
deposits
L. Simcoe
NIAGARA ESCARPMENT
terrain above escarpment
terrain below escarpment
Blue Mountain at the Caves
Mono Centre Outlier
1⅕ miles S.E. of Mono Mills
Lake Ontario
Niagara Falls
Hamilton
Lake Erie

Dundas Valley near Hamilton, the Devil's Glen at Singhampton, and the Beaver Valley at Thornbury. At Owen Sound and at Colpoy Bay portions of similar valleys have been drowned by the waters of Georgian Bay. The streams associated with these valleys today are obviously misfits, far too small to have carved them by themselves.

While rock forms the skeleton, so to speak, of the escarpment there are many areas where it has been buried beneath sand, clay, clay with boulders, and other surficial deposits. In some areas—for example, along Highway 89 between Alliston and Primrose, or along Highway 9 east of Mono Mills—we can see no bedrock, and sometimes wonder where the escarpment is. The unconsolidated deposits belong to a late phase of the region's history, just yesterday in geological time, when the glaciers advanced and retreated during the Pleistocene Epoch.

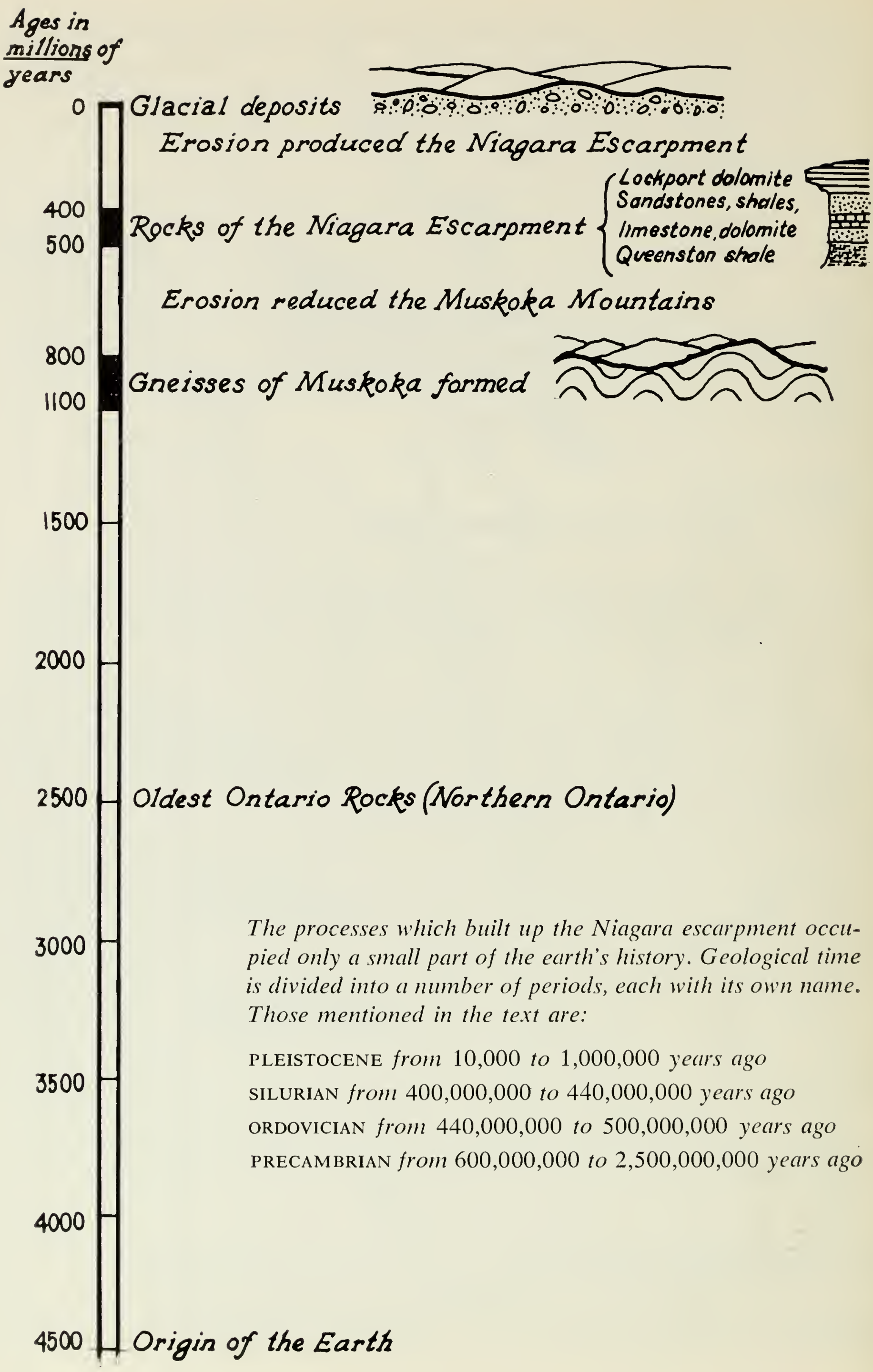
WHEN was the escarpment formed?

The history of the escarpment is locked within the rocky wall itself. The story emerges from evidence to be found in the layers which make it up, in the mantle of clay which partially covers them, and in the rocks of the surrounding area.

If you drill deep enough anywhere in southern Ontario you will eventually reach the ancient rocks of the Precambrian Shield—rocks familiar to many people because they surface in the Georgian Bay, Muskoka and Haliburton areas. They are about 1,000 million years old.

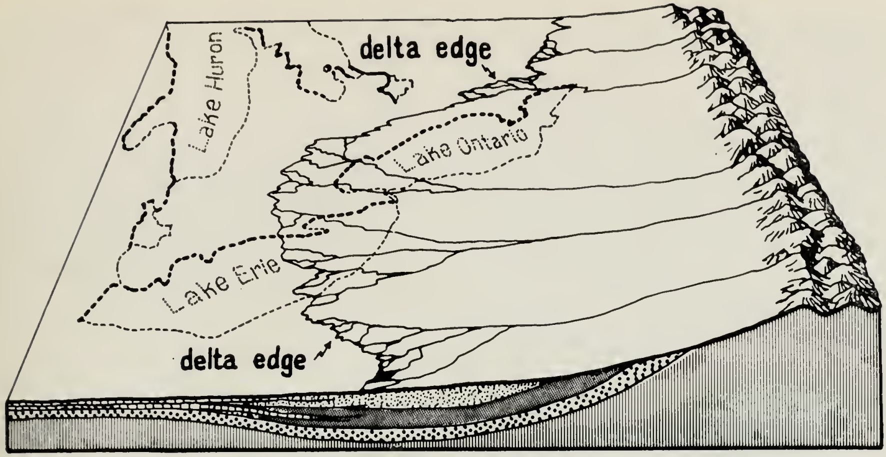
The typical Muskoka outcrop consists of gneiss (pronounced "nice"), a term which indicates a metamorphic rock, one which has been altered from something else. Geologists cannot be certain what the original materials of the gneisses were, but they are reasonably sure that the chemical and physical processes involved in their formation took place some five to ten miles below the earth's surface, in the roots of a mountain system. Thus, 1,000 million years ago there must have been "Muskoka Mountains" which would have rivalled any modern range. Since we see no such mountains there today—what happened to them? It is very simple, they were eroded away. Just think of the enormous time it must have taken to remove untold cubic miles of rock from these mountains, in order to reduce them to the nearly flat terrain we know today, and to expose their roots, the gneisses!

The face of the escarpment changes greatly from place to place between Niagara Falls and Tobermory. The different profiles shown on this map were caused by changes in the bedrock and deposition of glacial deposits; the indentations into the escarpment were caused by pre-glacial river erosion. (After Fremlin)



The processes which built up the Niagara escarpment occupied only a small part of the earth's history. Geological time is divided into a number of periods, each with its own name. Those mentioned in the text are:

PLEISTOCENE *from* 10,000 *to* 1,000,000 *years ago*
SILURIAN *from* 400,000,000 *to* 440,000,000 *years ago*
ORDOVICIAN *from* 440,000,000 *to* 500,000,000 *years ago*
PRECAMBRIAN *from* 600,000,000 *to* 2,500,000,000 *years ago*

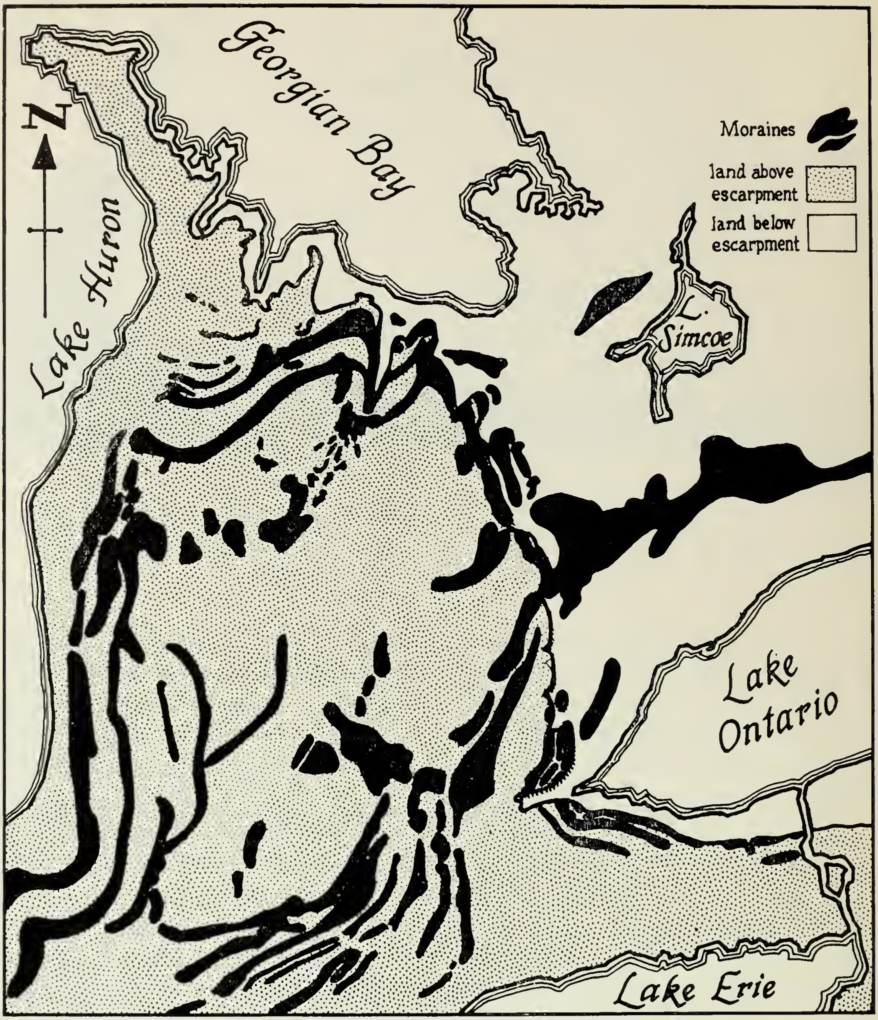


Silurian rivers, issuing from the young Appalachian mountains, built great deltas across much of southern Ontario and adjoining areas. Later, erosion removed the eastern portions of the deltas, but the western parts are preserved as sandstones and shales in the escarpment and sub-surface.

It is not surprising therefore that the next chapter in our history starts some 500 million years after the formation of the gneisses. Between 500 and 300 million years ago, seas periodically flooded southern Ontario. On their floors, a few thousand feet of sands, muds, sea shells and reefs buried the Precambrian surface. Some of these deposits became the rocks of the Niagara escarpment.

On the eastern shore of the seas, during Ordovician and early Silurian times, rose the young Appalachian Mountains. Rivers flowed from them to the inland seas, carrying sands and muds which formed large deltas at the river mouths. Seaward from the deltas, away from the muddy waters, calcareous sediments built up on the sea floor. Over an immense period of time the deltas turned to rock—the sandstones and shales of the southern section of the escarpment. Carbonate rocks such as the Manitoulin dolomite formed from the calcareous sediments. Eventually all the seas cleared of muddy sediment, and the Lockport-Amabel reefs flourished.

We talk of sediments turning into rocks. How did this happen? At first the sediments on the ancient sea floors contained a considerable amount of water in the pores between individual grains of sand and mud. But as succeeding layers slowly built up, downward pressure from their weight forced this trapped water from the bottom layers. At the same time, or perhaps later, deposits of certain minerals—limonite (iron oxide), quartz (silicon dioxide), calcite (calcium carbonate) or dolomite (calcium magnesium carbonate)—formed between the grains, and cemented the whole mass. The process (lithification, or cementation), took a long, long time.



Over the bedrock carved by erosion, the glaciers abandoned deposits of clays, sands and gravels in the course of their retreat. These moraines mask much of the escarpment face and are associated with a great system of moraines in southwestern Ontario. (After Chapman and Putnam)

The final retreat of the seas, perhaps 300 million years ago, left a blanket of sediments thousands of feet thick over the Precambrian surface. In this blanket the basic materials of the Niagara escarpment were only a part—probably buried. To shape the escarpment and expose its framework required about 300 million years. Further important changes in the terrain

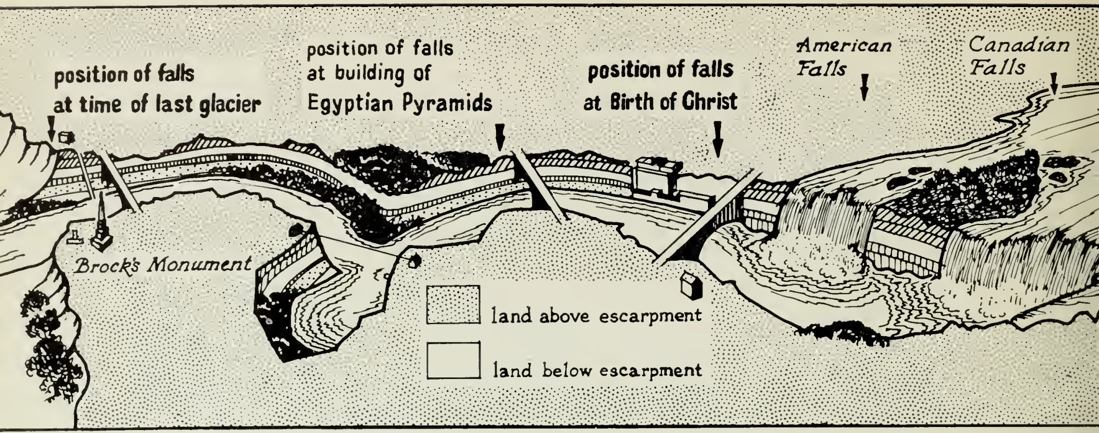
Moraines, left by the glaciers, mask the rocky framework of the escarpment in Albion Township.

began with the Ice Ages one million years ago. Finally came a mere 10,000 to 12,000 years of post-glacial erosion which is still slowly altering the appearance of this outstanding Ontario landmark.

HOW was the escarpment shaped?

The ancient seas left behind them a flat, featureless limestone plain. From it an ever-changing pattern of rivers carved the Niagara escarpment. By the time the first glaciers advanced a million years ago, the escarpment looked essentially the way it does today.

While the geography of these ancient waterways will never be known exactly, we can make deductions from the traces they have left. In general they followed the slopes of the Algonquin Arch. During the last phases of the preglacial drainage pattern one river almost certainly entered the Georgian Bay basin, probably flowing northwards from the Lake Simcoe


position of falls at time of last glacier
position of falls at building of Egyptian Pyramids
position of falls at Birth of Christ
American Falls
Canadian Falls
Brock's Monument
land above escarpment
land below escarpment

The erosion which has created the escarpment is most rapid at Niagara Falls. Here the force of cascading water has cut a gorge seven miles long in only 12,000 years.

region or the crest of the Arch in that area. We can say this because at the north end of the escarpment we find deeply incised valleys such as the Beaver Valley, Owen Sound and Colpoy Bay. These valleys have a general trend toward the northeast, indicating that the streams in them ran in that direction and likely fed into a main stream flowing to the north or northwest.

We can find traces of another river to the south. Drilling in the Richmond Hill area shows a large valley in the bedrock beneath the glacial deposits. This valley must have contained a river running southeast into the Lake Ontario basin. In that case, there must have been a divide in the Lake Simcoe area from which streams ran northward and southward.

The ultimate outlet for the waters of the preglacial river system—whether it was to the Gulf of Mexico via the Mississippi Valley, or to the Atlantic Ocean, or both—has been a subject for argument for over half a century. The weight of current evidence suggests that the water drained through the Mississippi Valley. More information, however, will be forthcoming from drilling, and from direct underwater observation by skindivers trained to spot old watercourses on lake bottoms.

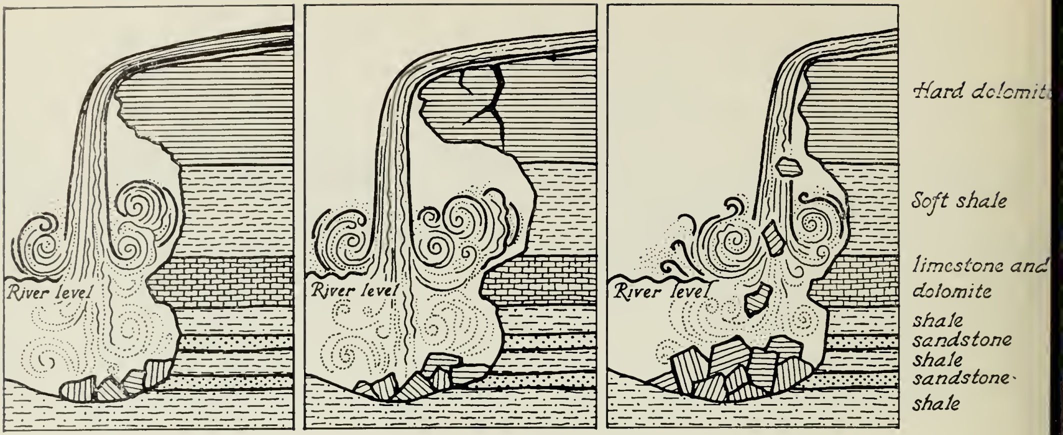
Today we can still see the details of the erosional process which shaped the escarpment. Streams and rivers continue to carve valleys into the escarpment wall: Spencer Creek at Webster's Falls, above Dundas, for example, and the Credit River at its forks. In craggy segments such as the headlands of Cape Croker, Osler's Bluff, parts of the Beaver Valley, and above Milton, the explorer can find accumulations of large angular blocks of dolomite, called talus, that have slumped off the vertical wall. The "caves" at Collingwood are also in such an environment. In areas like these we can see how, over scores of millions of years, the escarpment worked its way westward across the southern part of the province. Here and there we can also see where the process has not been complete, and has left outliers cut off from the main escarpment, as at Mono Centre and near Creemore.

We have no way of estimating the rate at which the Niagara escarpment has eroded. The only figures available are for Niagara Falls, which are slowly retreating upstream as the rock face recedes beneath the force of the cascading waters. Before remedial work began near the Canadian Falls, the retreat was estimated to be about 3½ feet per year. But obviously this is a special case because of the large size of the Niagara River, and no other part of the escarpment is being changed so rapidly.

You may also find true caves in some areas of the escarpment. These developed where surface and ground waters, working along joints and in some cases along certain lines of stratification, have dissolved out soluble material. One example is Mackenzie's Cave, on Bronte Creek, where William Lyon Mackenzie is said to have taken refuge in 1837 after the failure of his rebellion. In other instances, waves from preglacial lakes appear to have eroded out large amphitheatres along the cliffs. These features, which are not really caves at all, are most common on the Bruce Peninsula, for example at Hope Bay. Cave exploration is growing in popularity and many new ones will be found along the escarpment: to the geologist they are further evidence of continuing erosion.

The shaping of the escarpment entered a second phase with the beginning of the Ice Age—one of building up as well as of tearing down. The glaciers advanced and retreated four times in this area during the Pleistocene Epoch. During the advances, their main effect was to plane off and smooth the sides of the valleys through which they moved; at these times they also polished and scratched the bedrock over which they passed. We are most aware, however, of the effects of their final retreat, which left behind areas of large, irregular hills called moraines. These show where the glacier paused while it was melting away. Moraines are associated with the escarpment in many areas, such as in the neighbourhood of Orangeville, Glen Huron, and Flesherton. They are made up of heterogeneous mixtures of clays, sands, gravels and boulders which were carried to the front or edge of the glacier by flowing ice, and abandoned there as the glacier retreated. In some cases it is possible to identify the place of origin of certain pebbles and boulders found in the moraines. Such methods, together with the morainal pattern, indicate that the glaciers advanced from different directions over different parts of the escarpment.

When the glaciers melted, they released vast quantities of water. Huge



The sapping process is shown at its most classic location, Niagara Falls. Notice how the hard dolomite is undermined as the swirling water wears away the soft shales. The layer of hard dolomite at the crest of the Falls can be traced along the top of the Niagara gorge and the length of the escarpment.

rivers carrying tons of mud, sand and gravel coursed through the moraines. Some of the sediment was deposited along the spillways; this is the origin of the gravel being excavated south of Caledon.

One of the most interesting spillways can be seen at Mono Centre, where a river flowed between the main escarpment and an outlier. The broader development of this ancient water course can be seen a little further north, on Highway 89 between Violet Hill and Primrose. The Violet Hill spillway and others associated with it discharged their waters into the Erie and Huron basins. With the withdrawal of the glacier northward and eastward, the meltwaters flowed between the ice front and the escarpment wall, down the valley of the Credit and perhaps other rivers, such as the Humber, into the Lake Ontario basin.

During the final phase of deglaciation, the ancestral Great Lakes formed. In places the escarpment was their shoreline and was modified by wave action. Between Craigleith and Meaford, and at Queenston just below Brock's monument, you can find a step or break in the escarpment profile. It takes a keen eye, but it can be done by referring to maps dealing with glacial geology.

Thus the Niagara escarpment, carved from a featureless plain, helped to shape the post-glacial appearance of southern Ontario. The interplay between the retreating glaciers and the escarpment wall is perhaps one of the most interesting and intriguing parts of our glacial history.

Why was the Niagara escarpment formed?

The answer to this question lies in the rocks of the escarpment—their nature, their succession, and their response to erosion by running water. Most important of all is the cap of Lockport dolomite, which is hard and resistant, whereas the underlying rocks are softer and more easily worn away. Thus with time the Lockport dolomite becomes undermined; rock falls occur, and form talus slopes. In the overall process a vertical face, or escarpment, is maintained. This process, called sapping, is most active where rivers cross the escarpment or have become established on its face.

WHO has studied the Niagara escarpment?

One of the earliest descriptions was written by Sir William Logan, first director of the Geological Survey of Canada. In *Geology of Canada*, published in 1863, he wrote of the "Middle Silurian escarpment" and the ravines notched into it:

> It is by these ravines and gorges cut clean through the solid limestone [Lockport dolomite] and far down into the soft red marls below [Queenston shale] that the waters . . . find an outlet to the valley. These ravines afford scenes of the wildest and most picturesque confusion. Great blocks and fallen masses of limestone, which in many cases is seen towering 200 feet above, lie scattered over the bottom of the gorge while others constitute a talus at the base of the precipice, as if to form it a whole cliff had been shaken into mighty fragments, among which are holes and interstices so numerous, large and deep, that it is dangerous to pass along.

Even before Logan, geologists of Canada and the United States had begun a series of studies of the Niagara escarpment, its rocky face and the fossils contained within it. The work is still under way. Important collections from these projects are housed in universities and museums in Canada and the United States.

Field and laboratory studies of the Niagara escarpment have formed the basis for many government reports and university dissertations. From all this work, much of it detailed, the escarpment has been found to hold a unique position in the record of Silurian events. As such, it still commands the attention of everyone interested in studies of facies changes and historical geology.

While the bedrock has been thoroughly examined, the same cannot be said for glacial phenomena connected with the escarpment. From the pioneer studies of Leverett and Taylor to the regional work of Chapman and Putnam, much has been learned. The detailed mapping being carried out by Karrow and others is still required, however, before our knowledge of the Pleistocene surficial deposits matches that of the Silurian bedrock.

No matter how much is written by the expert about the escarpment, it remains an ideal region for study and enjoyment by the amateur. Here you, the reader, can observe for yourself many of the processes which over 1,000 million years have moulded, and still mould, our physical environment.

At Tobermory, the dolomites of the escarpment disappear beneath the waters of Lake Huron.

SUGGESTED READING

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For the exploration of the Niagara escarpment, maps of the National Topographic Series on a scale of 1:50,000 (1″ = 0.8 mi. approx.) are best.